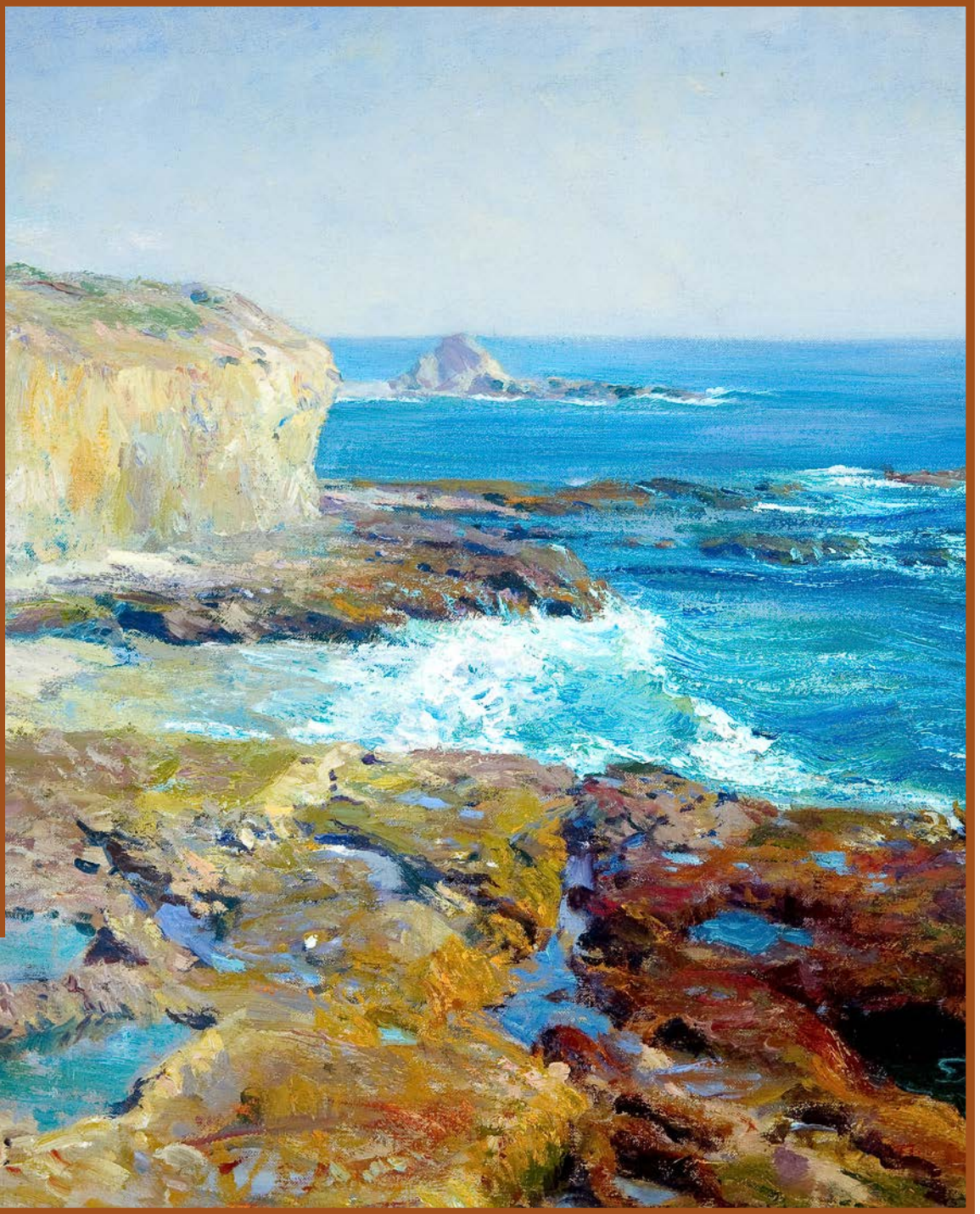




Earth Science  
Standard  
E.5.d.



# Ocean Currents and Natural Systems

## **California Education and the Environment Initiative**

Approved by the California State Board of Education, 2010

### **The Education and the Environment Initiative Curriculum is a cooperative endeavor of the following entities:**

California Environmental Protection Agency  
California Natural Resources Agency  
California State Board of Education  
California Department of Education  
Department of Resources Recycling and Recovery (CalRecycle)

### **Key Partners:**

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### **Office of Education and the Environment**

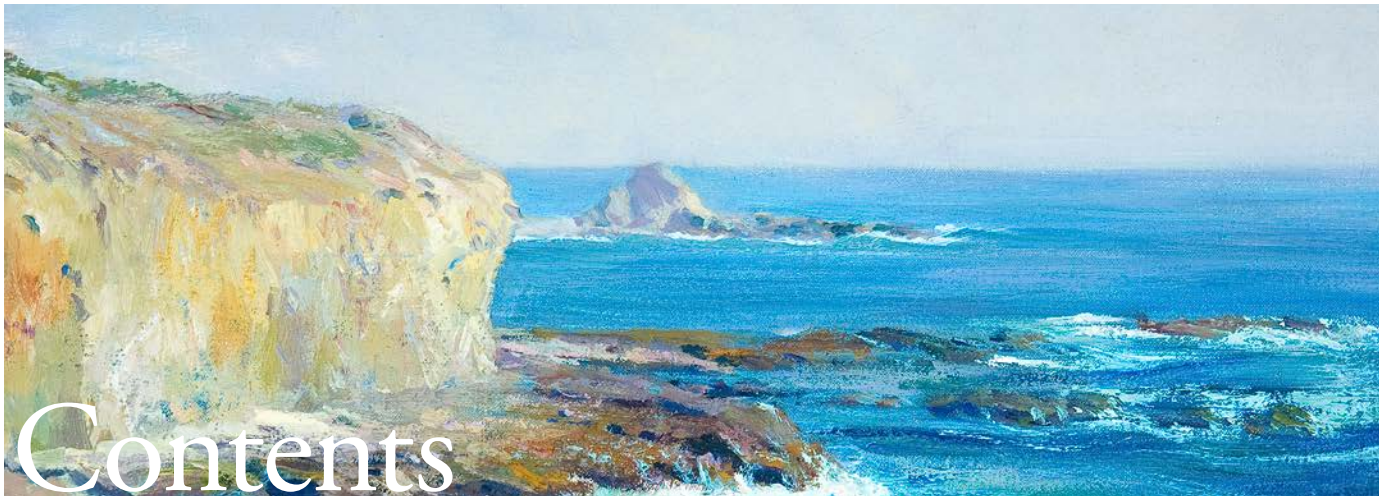
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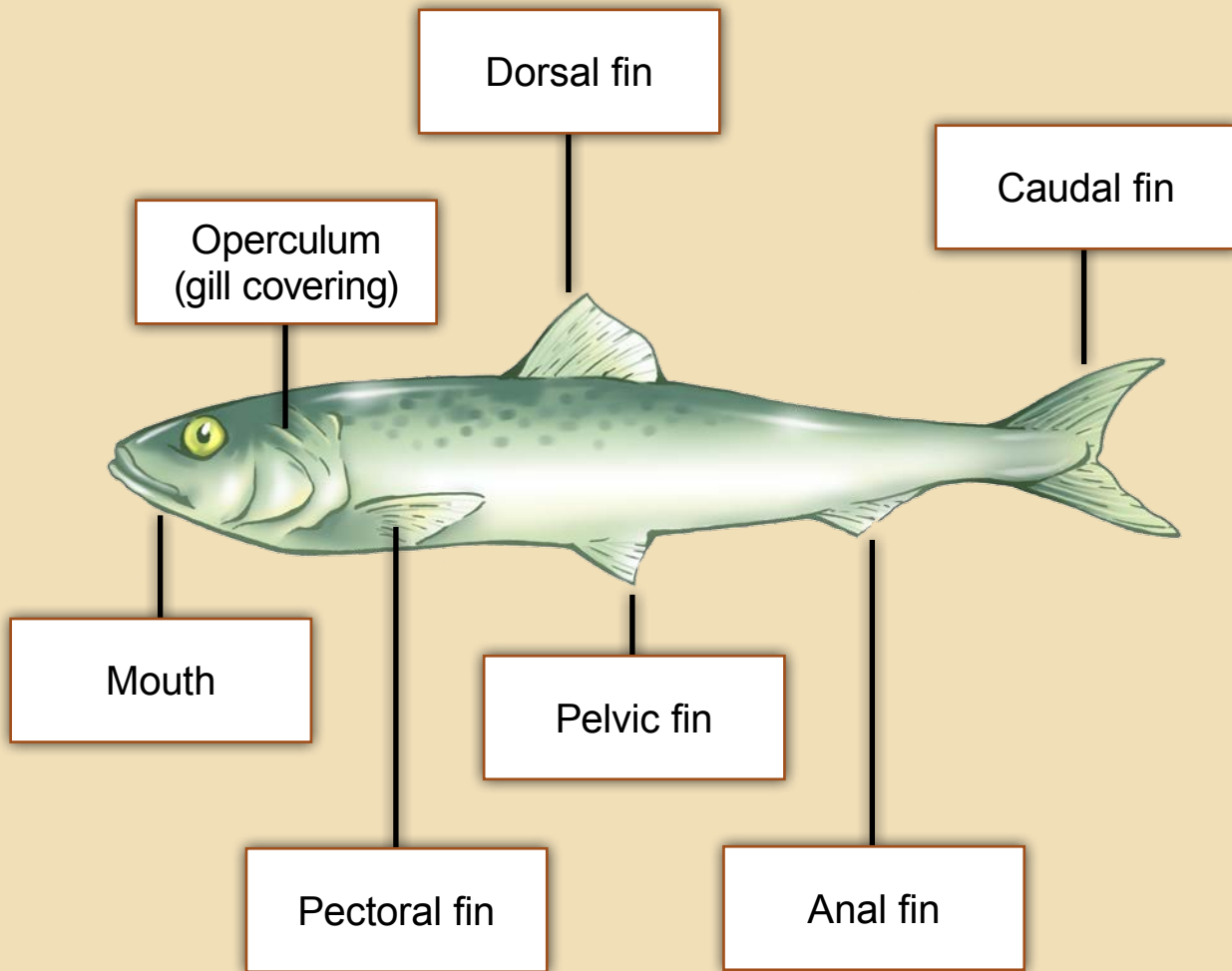
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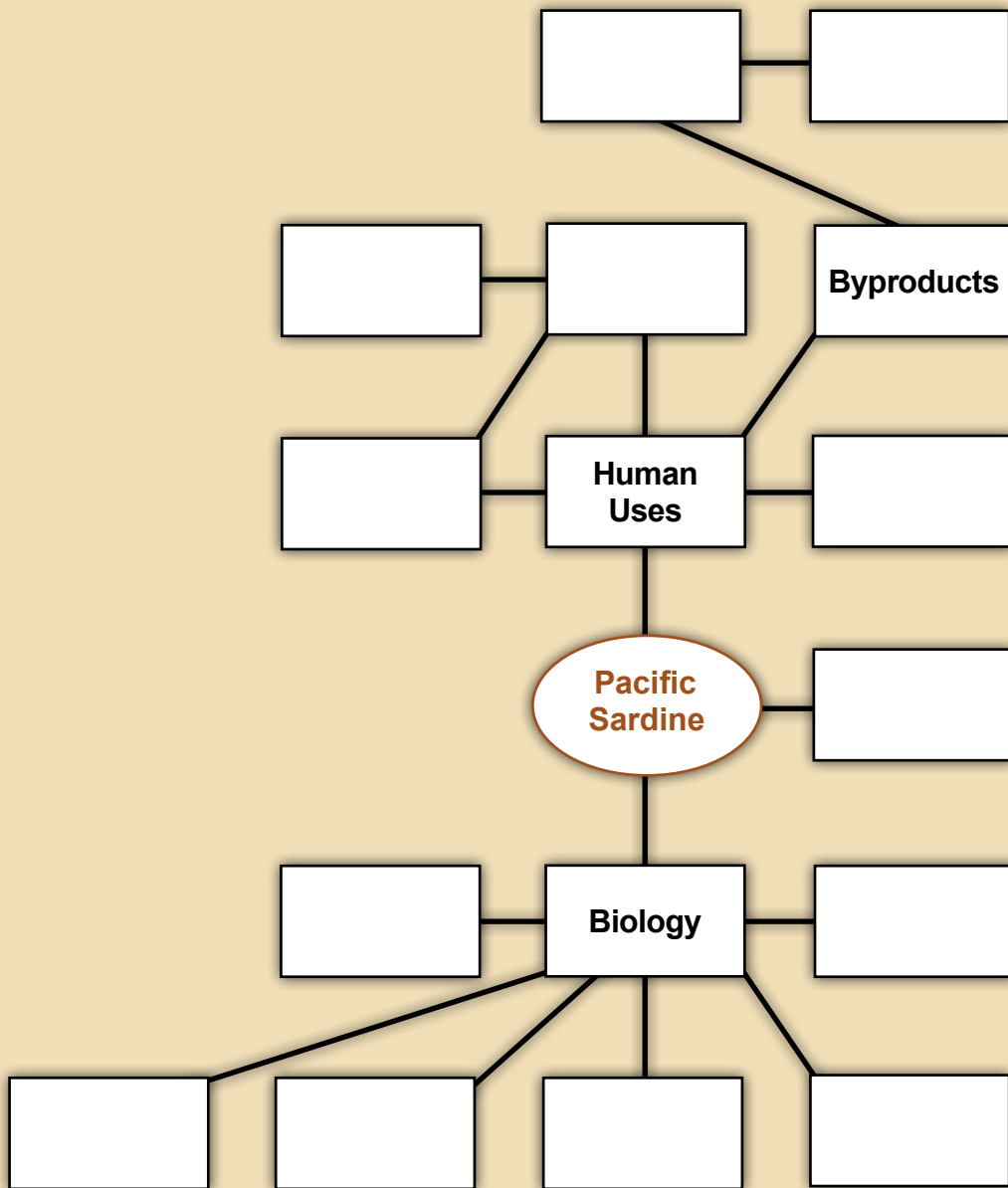
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## VA #1 Pacific Sardine Structure Key



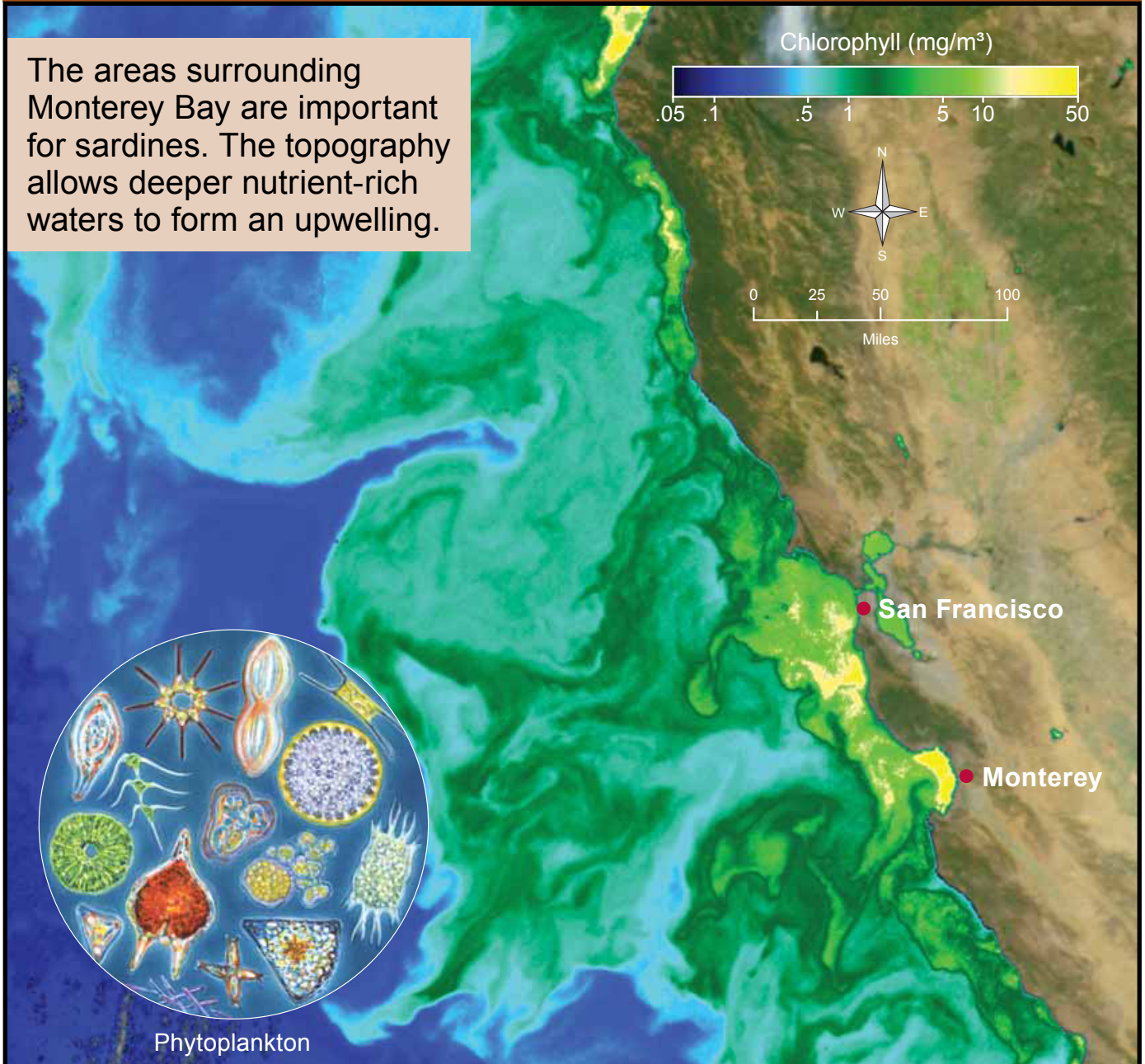
**VA #2 California Sardine Industry Timeline**


## VA #3 Physical Environment and Sardines Fisheries



## VA #4 Monterey Bay and Surrounding Areas

The areas surrounding Monterey Bay are important for sardines. The topography allows deeper nutrient-rich waters to form an upwelling.

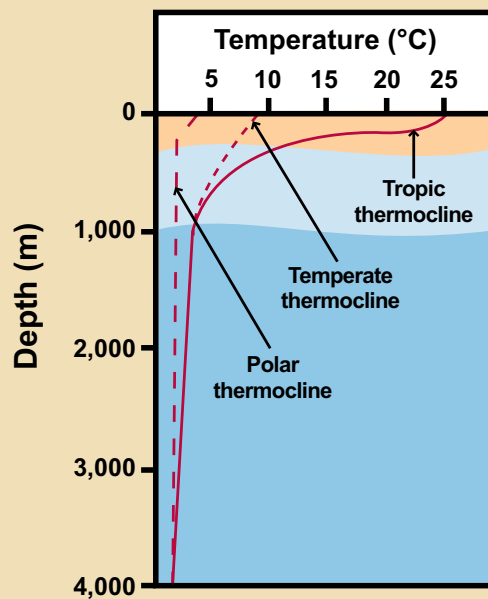
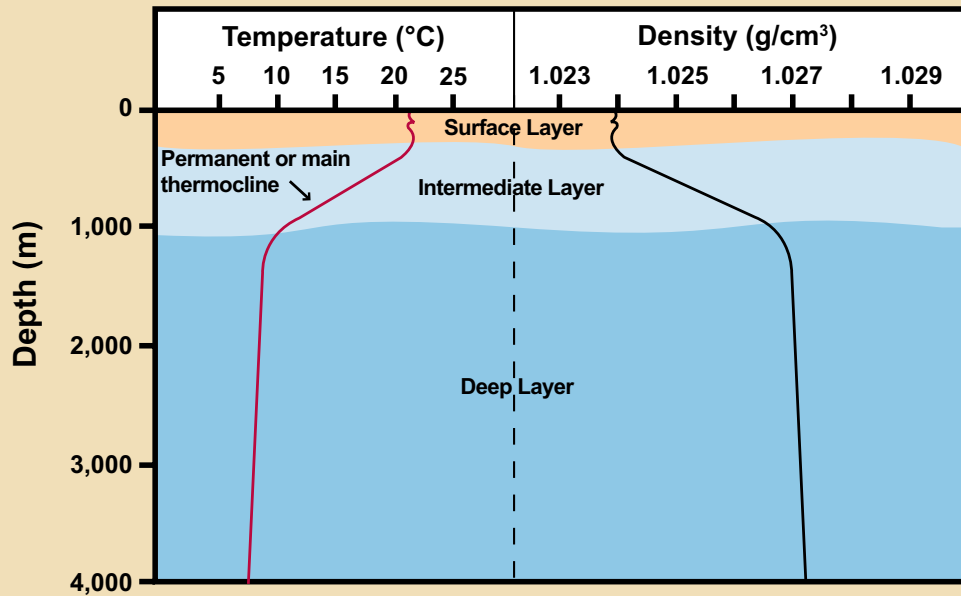




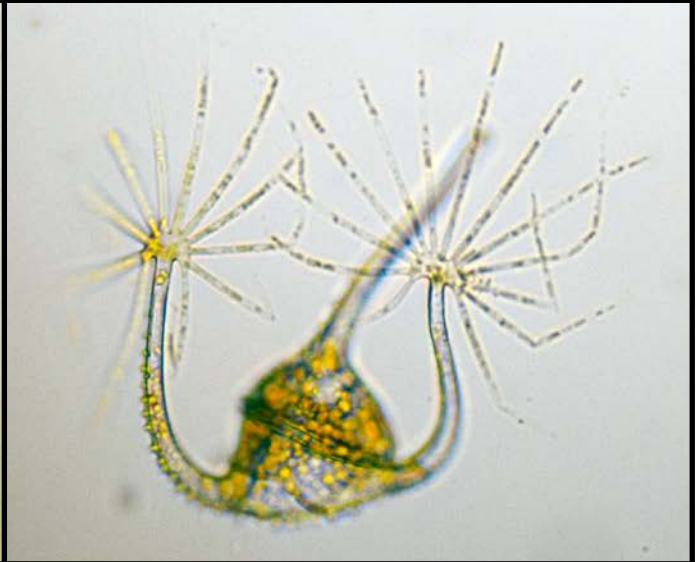
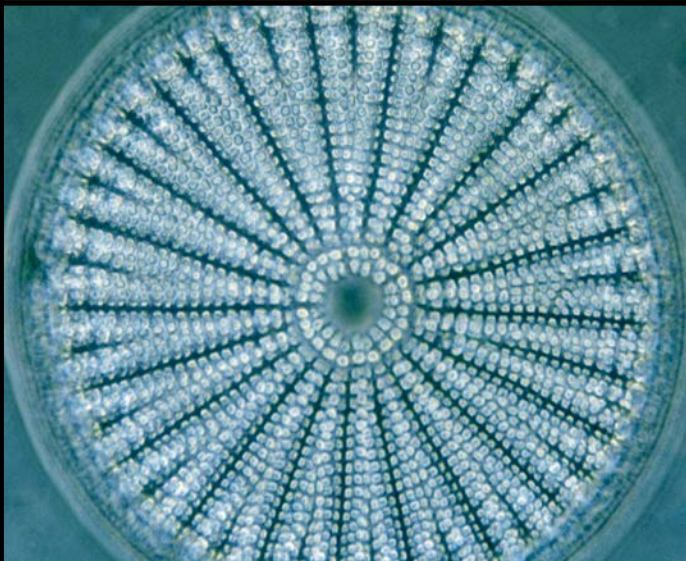
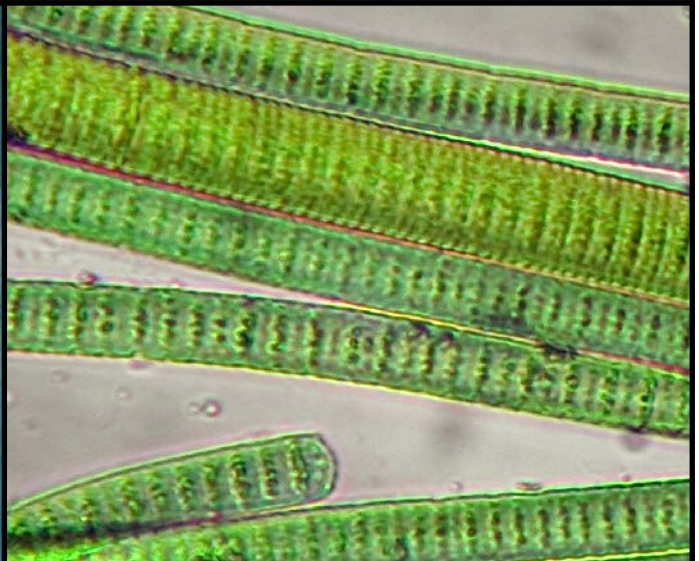
## VA #5 Ocean Layering Experiment

- Pour 100 ml of room-temperature tap water into a 500 ml beaker.
- Add two cubes of ice and let them melt.
- Measure and record the water temperature on the **Ocean Layering Data Sheet**. *(Note: Take the temperature the same way each time, with the thermometer in the same position. Allow sufficient time so that the reading on the thermometer is accurate.)*
- Add 50 ml of hot tap water to a glass container and record the temperature.
- Place a few drops of food coloring in the hot water and stir until the water is an even, dark color.
- Place a small sheet of plastic wrap on the surface of the cold water in the beaker.
- Carefully pour the hot, colored water from the glass container onto the plastic wrap.
- Slowly remove the plastic wrap.
- Observe what happens to the color in the water and describe any layering or mixing on **Ocean Layering Data Sheet**.
- Record the water temperature again.

## VA #6 Structured Layering of the Ocean

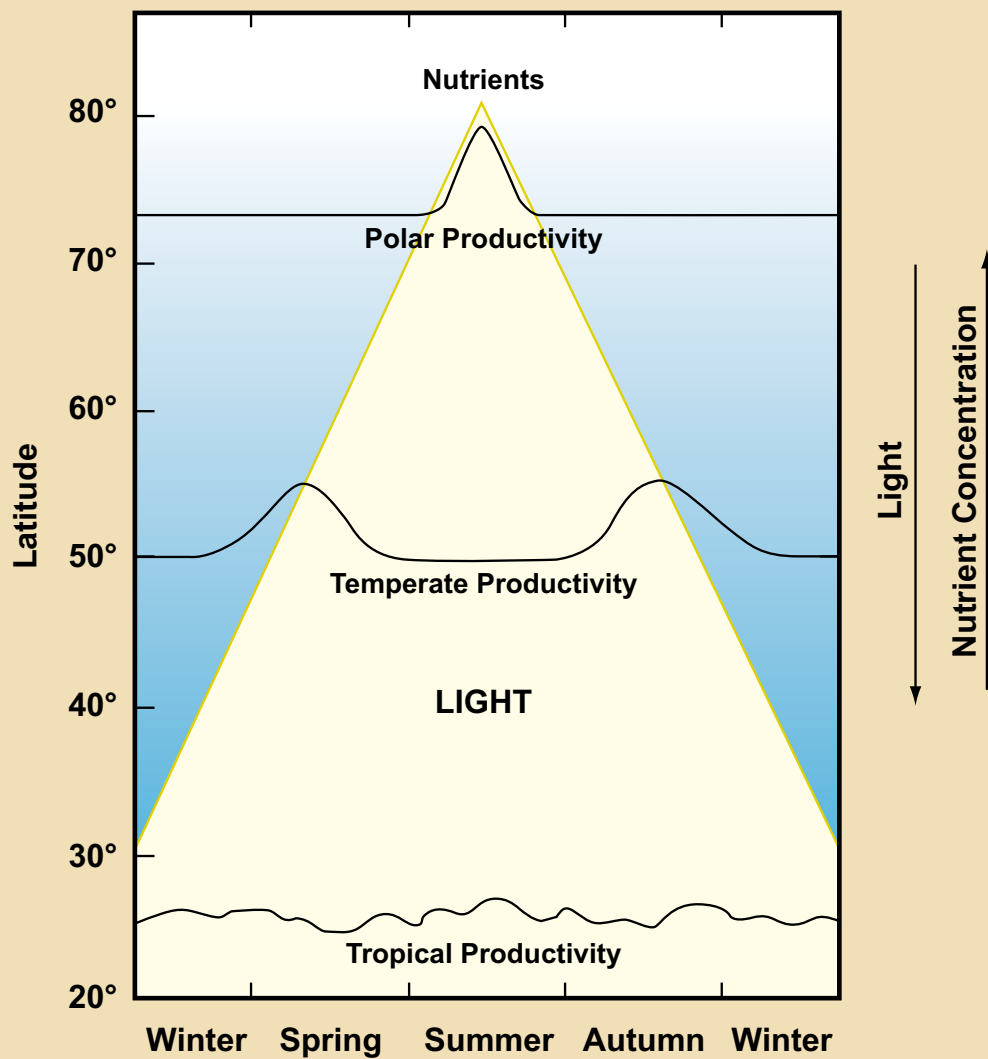


Source: Peter Castro and Michael Huber, *Marine Biology*, 6<sup>th</sup> ed. (New York: McGraw Hill, 2007), 59.

**VA #7 Phytoplankton****Colonial freshwater phytoplankton****Dinoflagellate****Diatom****Cyanobacteria**

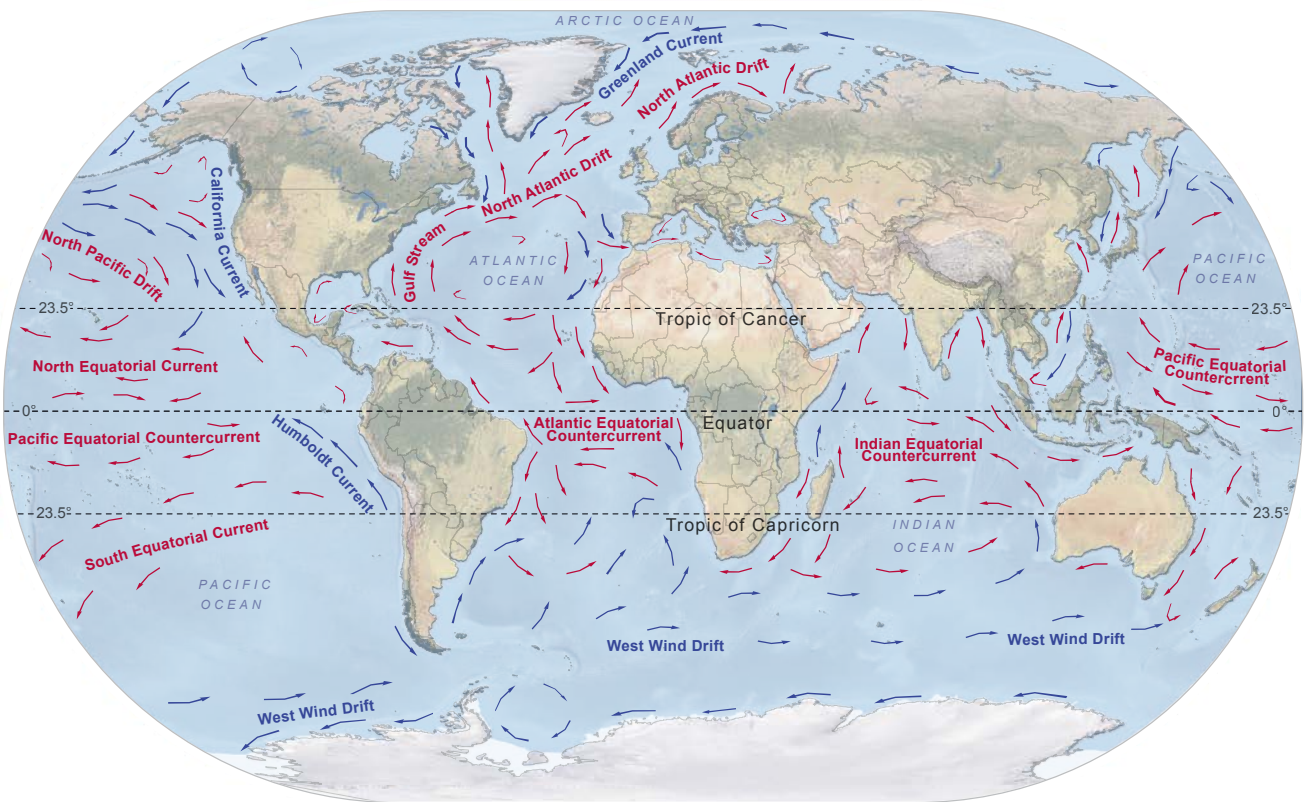
## VA #8 Seasonal Productivity in Surface Waters

This chart shows the relationship between the physical properties of the ocean environment and the biological productivity that occurs within it.

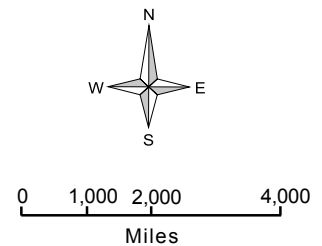




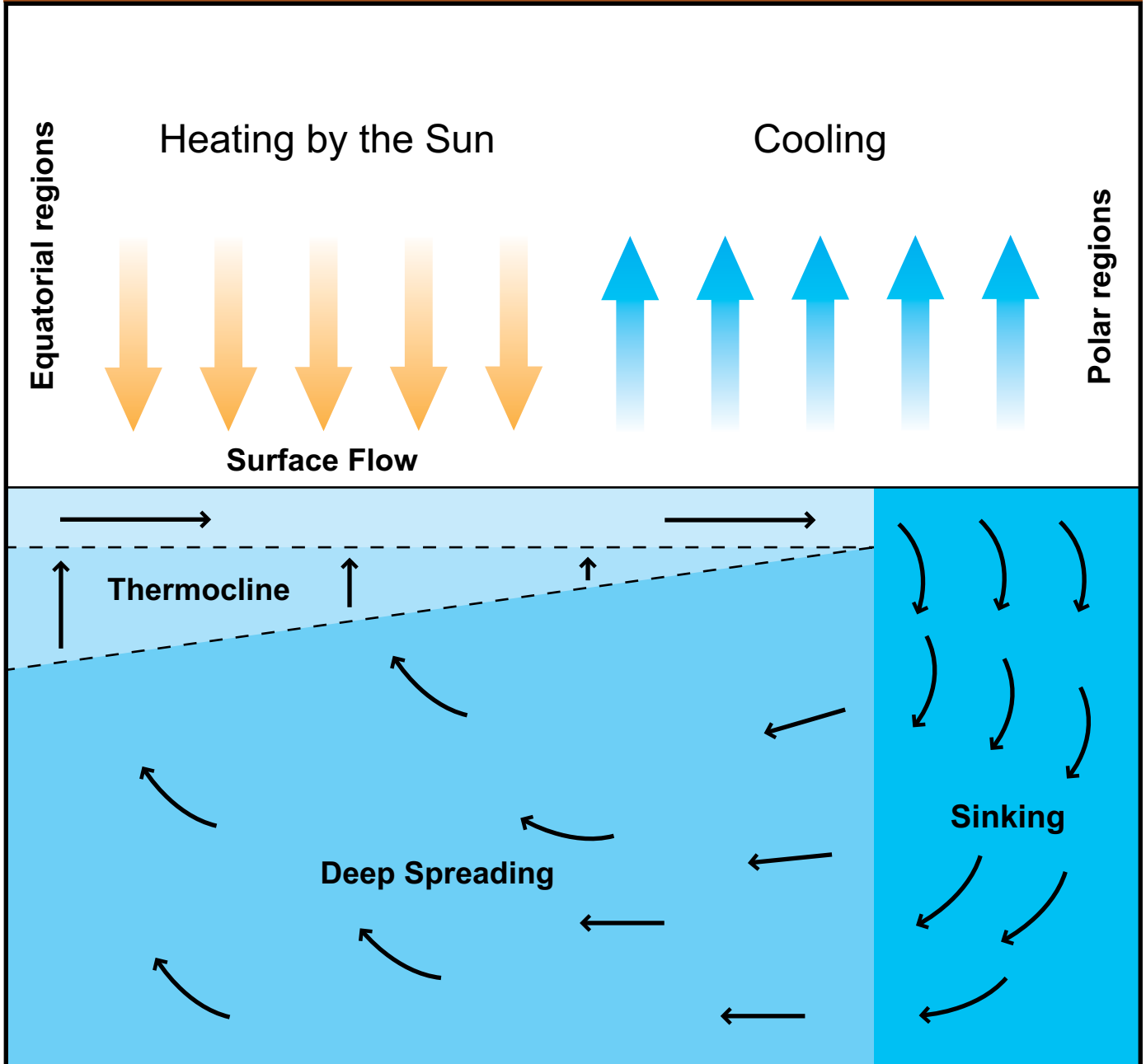
## VA #9 Major Ocean Currents



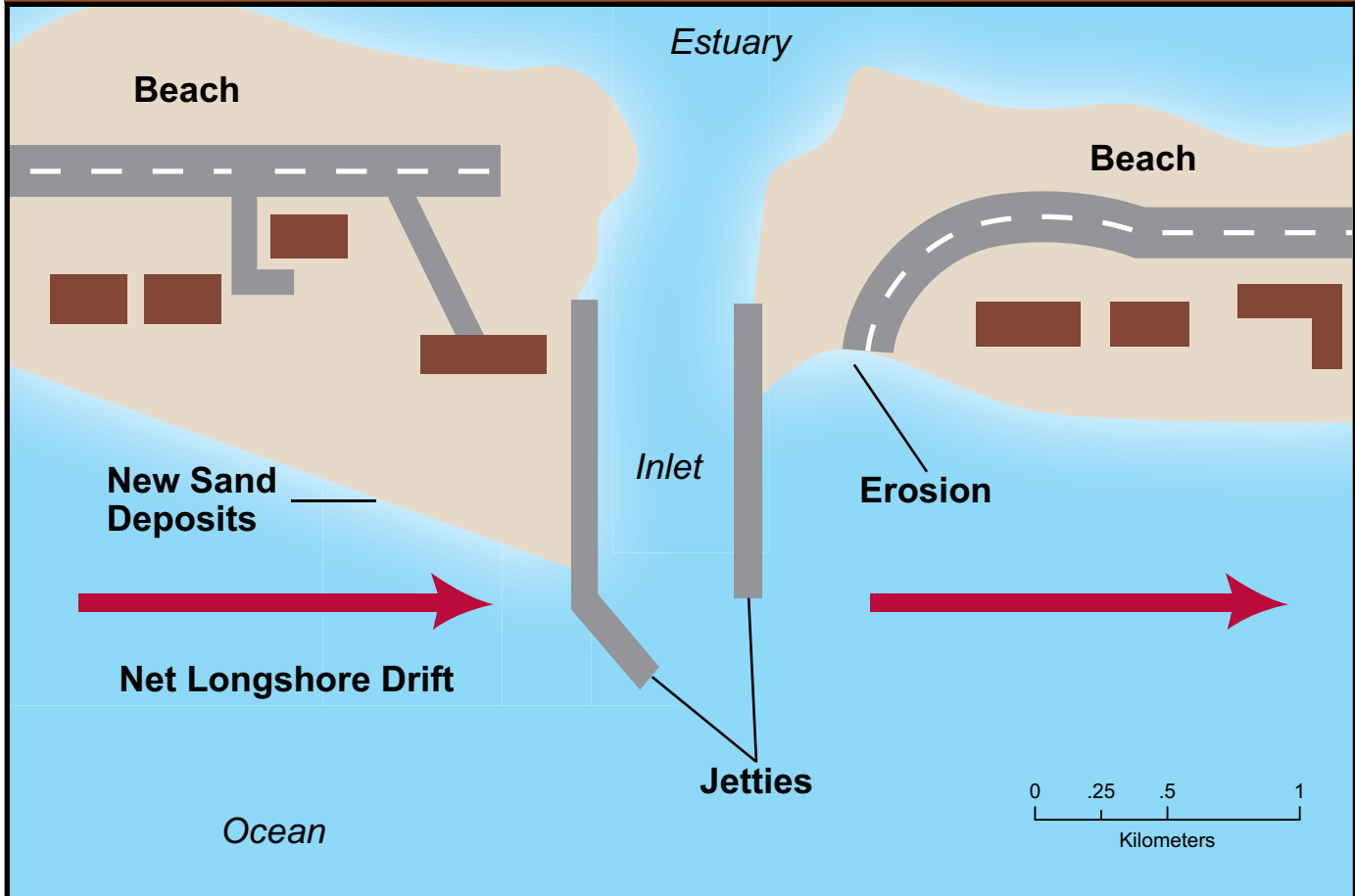
Warm Current  
Cold Current



## VA #10 Uneven Heating of Earth



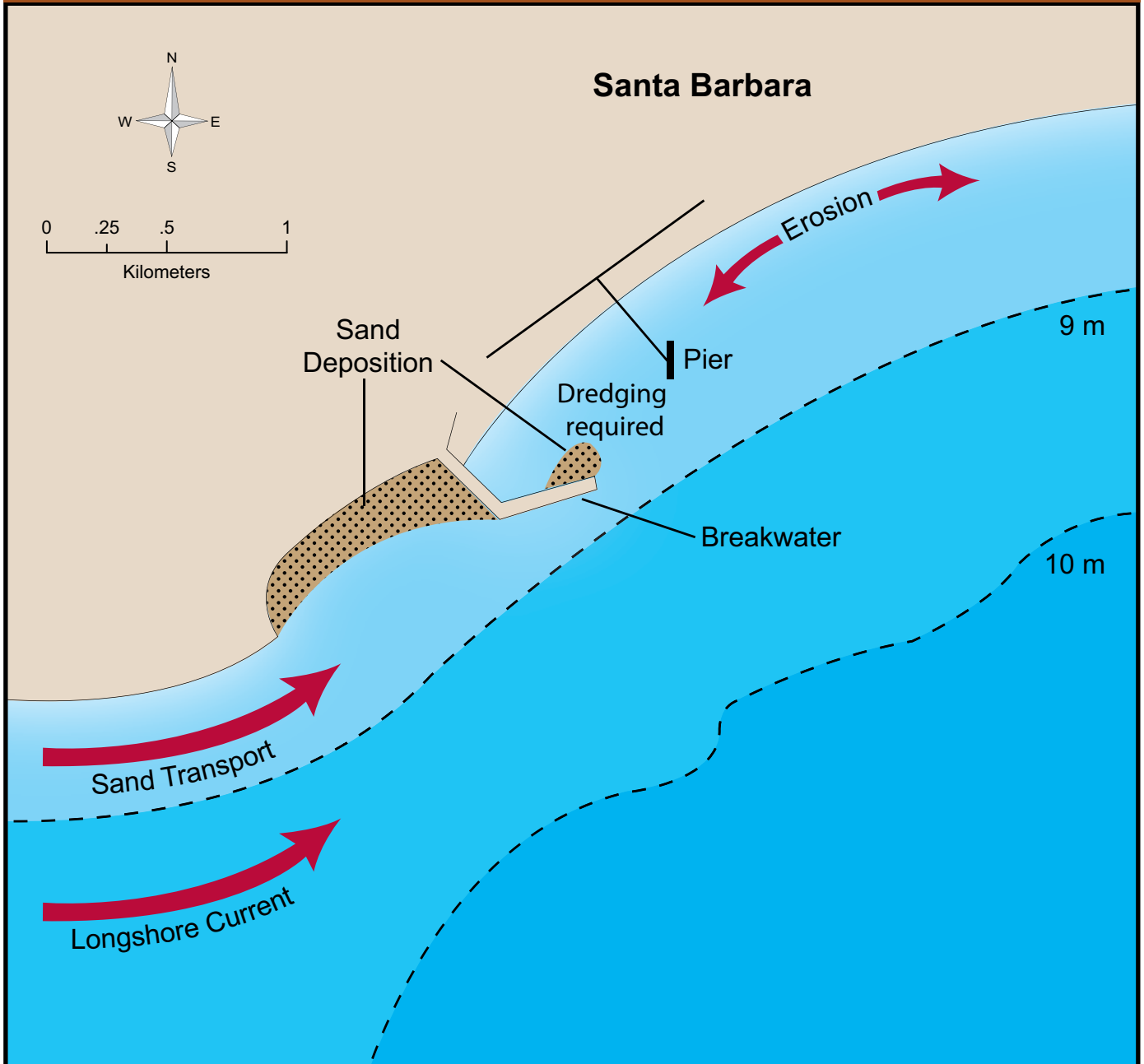
Source: Tom Garrison. *Essentials of Oceanography*. 2<sup>nd</sup> ed. Pacific Grove, CA: Brooks/Cole, 2001.

**VA #11 Jetties: Sand Deposition and Erosion**

Longshore currents flow parallel to the shoreline. The amount and pattern of sand deposition that results from the longshore current is called the “longshore drift.” The presence of a jetty results in the accumulation of sediments on the upcurrent side of the jetty and erosion on the downcurrent side. Wave action protects the inlets formed by jetties, allowing broad beaches to form. Jetties also provide new rocky reef habitat for organisms that would not ordinarily live so close to shore.

Source: Paul Pinet, *Invitation to Oceanography*, (Jones & Bartlett, 2005) 389.

## VA #12 Santa Barbara Breakwater





## VA #13 Santa Barbara Harbor and Breakwater

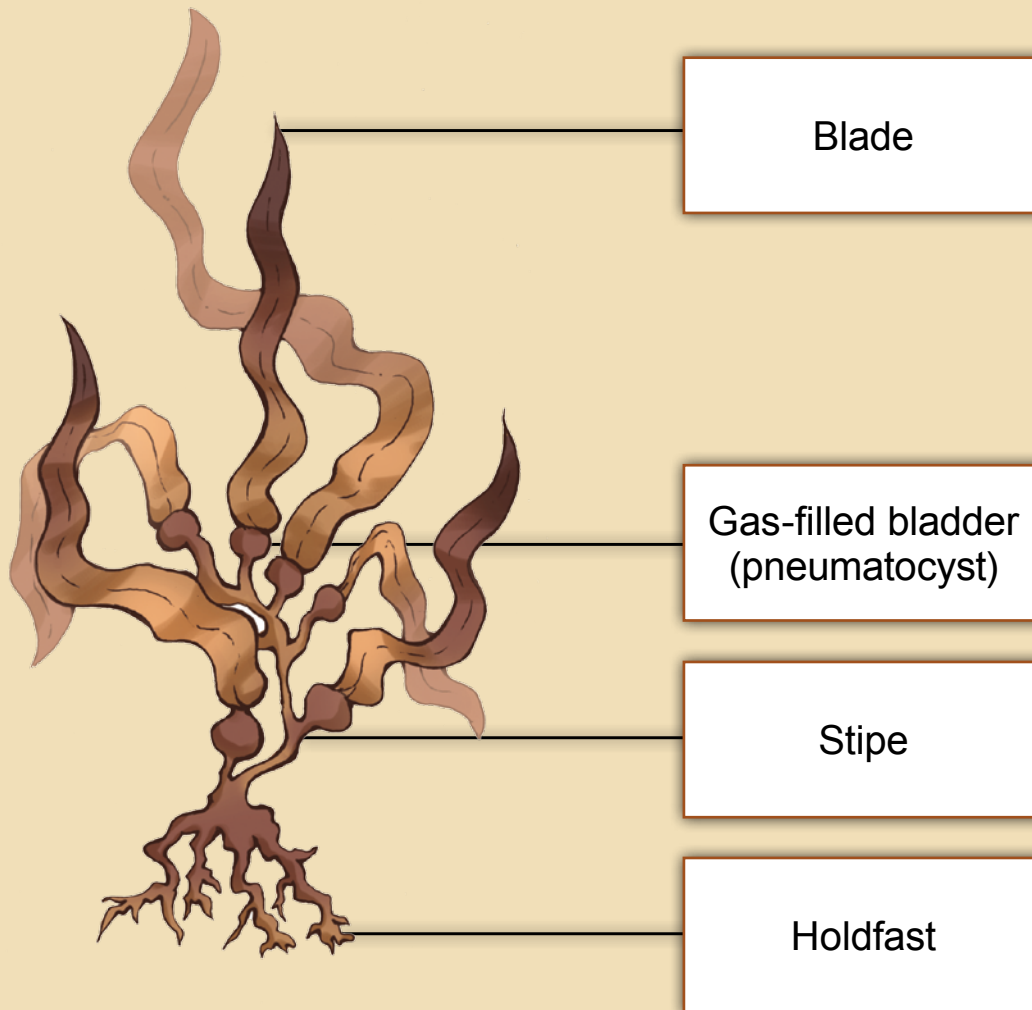




## VA #14 Dredging Santa Barbara Harbor



## VA #15 Structure of Kelp



Kelp is one of the largest and most complex of the brown algae. It anchors itself to the rocky ocean bottom with a holdfast and grows toward the surface. The blades are attached to a stipe. The gas-filled bladders (pneumatocysts) help the blades to float toward the sunlit surface.



## VA #16 Surface Kelp Forest Canopy



Kelp is a type of brown algae that grows rapidly—up to 50 centimeters per day in optimum conditions—toward the water’s sunlit surface. Holdfasts anchor kelp to the rocky ocean bottom in shallow waters. These characteristics result in a “forest” that extends from the bottom to the surface of the ocean and provides habitats for many species.



**VA #17 Products Containing Alginate**

Ice Cream



Mayonnaise



Jam



Toothpaste



## VA #18 Kelp Forest



Kelp forests are three-dimensional structures that provide habitat for many species. This photograph shows that many adult and juvenile fish make their homes in the forest. Harvesting kelp removes the upper layer of the kelp, destroying habitat and potentially affecting all of the organisms in the kelp forest.

## VA #19 California's Sardine Fishery 1945–1963

Date	Event
<b>1945</b>	An estimated 550,000 metric tons of sardines caught off the California coast. Catch greater than any other fish catch in North America. Twenty-four canneries operate along Cannery Row.
<b>1947</b>	Sardine fishery falls to 100,000 metric tons; and a tax imposed on fishermen to help support scientific research.
<b>1949</b>	Research collaborative established to investigate the sardine fishery's collapse. Participants include: Scripps Institution of Oceanography, the NOAA/NMFS Southwest Fisheries Science Center, and the California Department of Fish and Game. This group is later named the California Cooperative Oceanic Fisheries Investigations (CalCOFI).
<b>1957</b>	Ocean off California warms by 3.6° F (2° C), causing anomalies in precipitation, plankton abundance, and fisheries.
<b>1958</b>	Oceanographers, fishery personnel, and meteorologists conclude that understanding and forecasting fluctuations in coastal fisheries are best achieved by studying the entire ocean and ocean-atmosphere relationships.
<b>1960</b>	Approach to sardine question becomes more interdisciplinary and ecosystem based.
<b>1963</b>	First volume of CalCOFI atlas series describes temperature and salinity in the California Current.

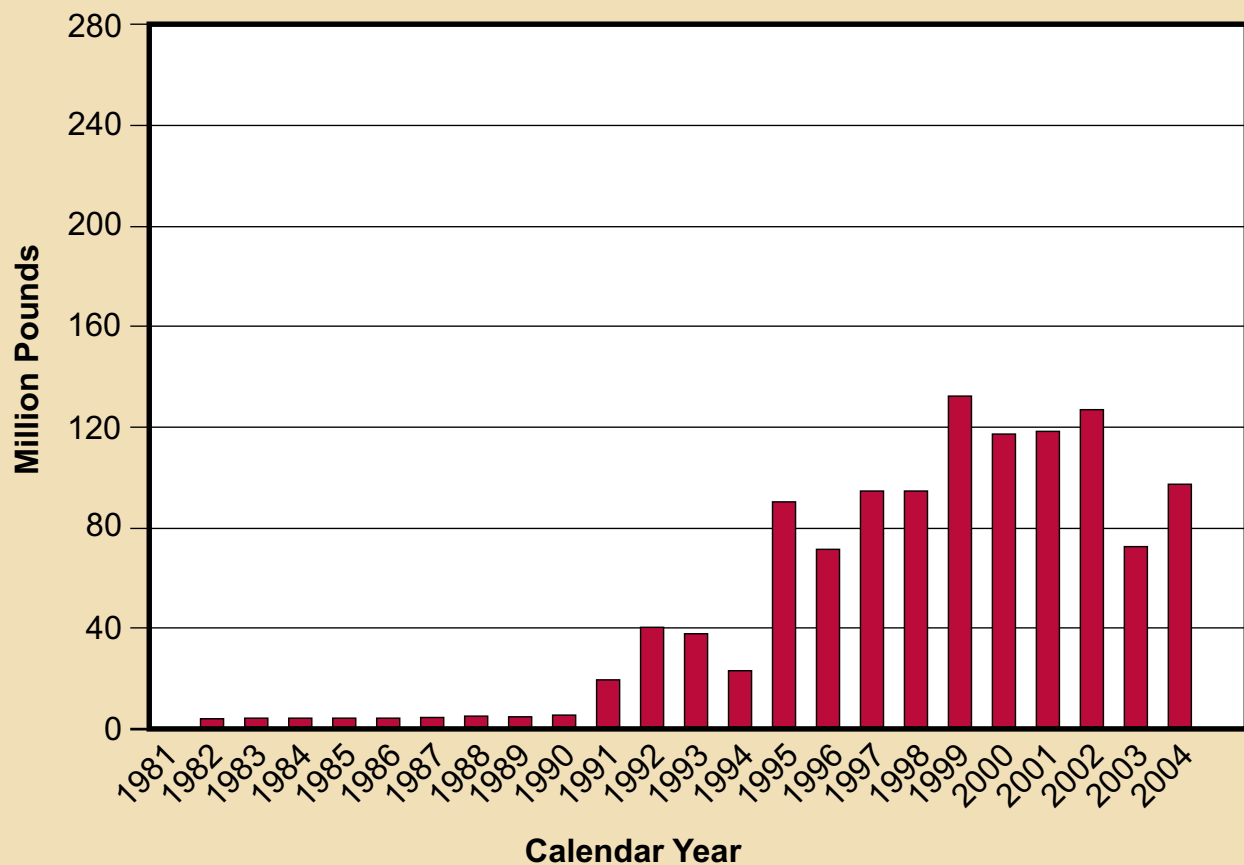
## VA #20 California's Sardine Fishery 1964–1985

Date	Event
<b>1964</b>	Sardine spawning biomass in this year (at 30,000 metric tons) is 1% of the spawning biomass of 1938. (Spawning biomass is an estimate of the total weight of the fish population. The sardine biomass estimate is based on a sample of fish eggs and plankton eggs.) State legislature enacts fishery moratorium.
<b>1969</b>	By counting fish scales taken from sediment off the Santa Barbara coast, CalCOFI scientists reconstruct an 1,800-year record that shows sardines follow a cycle of decline and recovery approximately every 30 to 60 years.
<b>1972</b>	Sardine spawning biomass minimum at less than 10,000 metric tons.
<b>1977</b>	Researchers observe long-term changes in sea-surface temperature, ocean circulation, and climate.
<b>1979</b>	Egg-production method, a new technique for measuring the size of the fishery, is introduced.
<b>1982</b>	Large anomalies in temperature and zooplankton biomass in the CalCOFI data first linked to tropical ocean warming phenomena.
<b>1983</b>	Quick-response study of 1983–1984 El Niño makes it one of the most thoroughly documented El Niño events to date.
<b>1985</b>	Sardine spawning biomass reaches 30,000 metric tons; the highest since 1964.



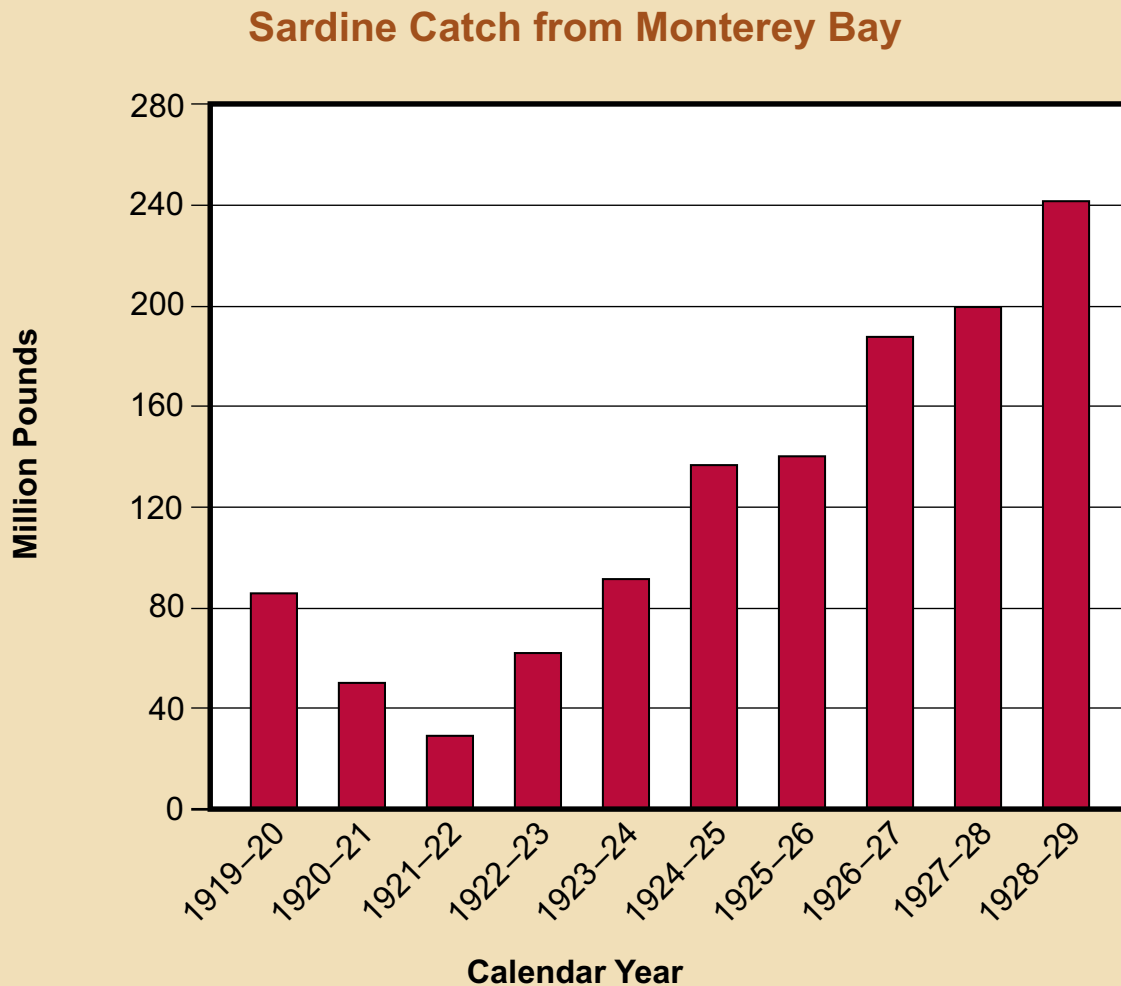
**VA #21 California's Sardine Fishery 1986–1999**

Date	Event
1986	California lifts its moratorium on sardine fishing in response to measured increases in spawning biomass.
1995	Sardine spawning biomass reaches 300,000 metric tons; the highest since 1954.
1998	Significant data compiled on consequences of El Niño to nutrient, chlorophyll, and zooplankton patterns in the California Current, providing a close look at links between ocean physics and biology.
1999	Spawning biomass of sardines exceeds 1 million metric tons for the first time since the CalCOFI surveys began in 1951.

**VA #22 Sardine Landings, 1981–2004****Pacific Sardine Landings**  
(*Sardinops sagax*)

Source: National Marine Fisheries Service, 2005

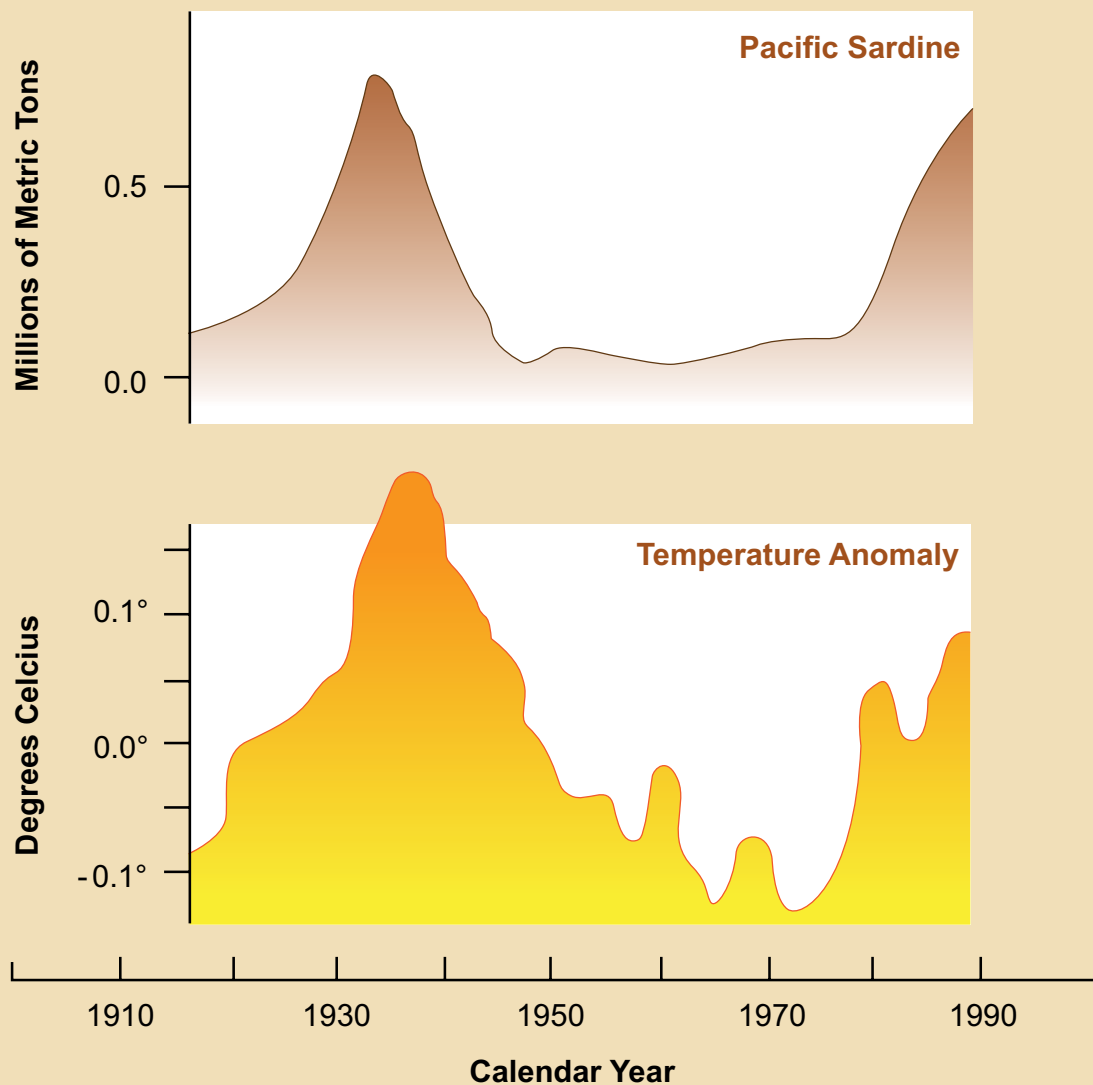
## VA #23 Sardine Catch from Monterey Bay, 1919–1929



Source: Milton J. Linder, Fishing Localities at Monterey from November, 1919, to March, 1929, for the Pacific Sardine (*Sardinops sagax*)

## VA #24 Sardine Catch and Ocean Temperature

### Correlation Between Pacific Sardine Abundance and Water Temperature



Source: Monterey Bay Aquarium. "Seafood Watch Pacific Sardine Report, Volume 1, 2004"

[http://www.montereybayaquarium.org/cr/cr\\_seafoodwatch/content/media/MBA\\_SeafoodWatch\\_PacificSardineReport.pdf](http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_PacificSardineReport.pdf)











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